LINGUISTIC REFERENCE IN SCIENCE: PROBLEMS AND PROGRESS

Dr. Koen B. Tanghe[Ugent, Belgium]

Alexis De Tiège

Dr. Stefaan Blancke

ABSTRACT

The crucial role that mathematical notation systems have played in the success of the hard or mathematical sciences is well known and richly documented: the origin of the history of these sophisticated notation systems more or less coincides with the birth of modern science. The role of our linguistic notation systems (as applied to, or used in, the scientific study of nature), by contrast, is hardly documented at all, at least not in a systematic way. We distinguish between (metaphorical and non-metaphorical) meta-scientific terms and scientific terms and, as far as the latter is concerned, between methodology and content terms. It is the latter sort of terms that interest us here. Five different dysfunctions in the relationship between scientific linguistic tokens and their referents will be presented and illustrated: scientific terms or phrases can not only be imprecise, they can also be meaningless, indiscriminate, inapt and ambiguous. By correcting or alleviating such dysfunctions, our linguistic notation systems have, in the course of the past four centuries, become more refined and functional scientific tools. This simple, illustrated taxonomy is not only historically relevant, it may also help contemporaneous scientists to identify and avoid possible pitfalls, associated with the use of language in science.

Keywords: notation systems, linguistic reference, scientific progress, terminological problems

INTRODUCTION

In his recent, 'new' and language-centric history of the sequence of events that we, since the early to mid-twentieth century, call the Scientific Revolution, David Wootton [1] rightly points out that the modern history of science, for all its talk of languages and discourses, "has not been nearly attentive enough to the emergence in the seventeenth century of a new language for doing natural science" (p. 48) and that "the basic history of some key words/concepts which make the scientific enterprise possible remains to be written" (ibid.). "This language reflected the revolution that science was undergoing, but it also made that revolution possible" (p. 249). He does not make the distinction himself, but the phrase 'Scientific Revolution' is, confusingly, used for both the remarkable revolution that, somewhere between the 15th and the 18th centuries, took place in the methodology we used for acquiring knowledge about the world (the methodological revolution), and for a number of actual 'revolutions' in our 'scientific' knowledge that occurred in the course of that same time frame (content revolutions). When discussing linguistic reference in science, we can and should make a corresponding distinction between science-methodology and science-content terms. It is only one of a number of terminological distinctions that we will introduce in section one, where the topic of the present paper will be situated in the larger body of extant scholarship on (the history of) notation systems, as applied to, or used in, science ('scientific notation systems'). That topic itself, a systematic survey of dysfunctions and (qualitative) progress in non-metaphorical science-content terminology, is elaborated in section 2.

1. The extant scholarship on scientific notation systems: a survey.

The most basic distinction that can be made, within the extant scholarship on scientific notation systems, is that between mathematical (including logic) notation systems and linguistic notation systems. The central role that mathematical notation systems played and play in the success of the hard or mathematical sciences is well illustrated by the historical fact that the origin of the history of these notation systems more or less coincides with the birth of modern science. Mathematics was originally, apart from number systems and a few other, isolated exceptions, indeed mostly written verbally or rhetorically, often even in metered poetry.[1] Euclid's *Elements*, for example, hardly contained any mathematical symbols. Even Galileo still formulated his laws of uniformly accelerated motion verbally. In the course of the past four centuries, mathematicians not only invented new notation systems (for new or for existing branches of mathematics), the best systems also seem to have invariably won out (an example of 'epistemological selection'). Mazur [2] gives the example of negative numbers (real numbers that are less than zero). As soon as they were accepted as numbers, there was great debate about how to write them. As late as the 19th century, some mathematicians asserted that negative numbers should be written as positive numbers flipped horizontally, in spite of the evident confusion this would engender for numbers containing a '0' or an '8', or for letters like 'b' and 'd'.[2]

As to linguistic notation systems, the main though somewhat fluid distinction is that between metaphorical and non-metaphorical (literal) terms. There exists a rich and interesting literature on the widespread but double edged and, hence, ambivalently valued use of metaphors in science and in particular in the non-mathematical sciences (see, e.g., [3]). A related topic is the so-called rhetoric of science: the use, by scientists, of rhetorical techniques to persuade their peers. As to literal terms and phrases: a first distinction that we can make is that between meta-scientific terms and scientific terms sensu stricto. The former are terms and phrases like 'the Scientific Revolution', 'revolution', 'science', 'scientist' [4], 'biology' or 'physicist', that we use to talk and think about the scientific enterprise and its many branches. It is interesting to note, as an aside, that whereas the phrase 'the Scientific Revolution' seems to have been first coined by the American philosopher John Dewey in 1915, contemporaries of this historic upheaval, like Robert Hooke, spoke of a Reformation in (natural) Philosophy (cf. [1], p. 34), which may be a more accurate phrase (it is, as a matter of fact, only in the 19th century that the term 'science' began to be commonly used for what, until then, had been generally known as 'natural philosophy').

---

[1] Examples of early, isolated and 'infertile' mathematical notation systems are Diophantus' third century BC algebraic notation and Oresme's 14th century notation for powers with rational exponents.
[2] Some mathematicians even denoted negative numbers with a waxing moon symbol, and positive numbers with a waning moon symbol.

It are the terms that were central to that (methodological) 'Reformation' in or of natural philosophy that Wootton refers to when he speaks about "a new language for doing natural science." It is indeed remarkable that this new language has, as yet, not received more attention. The main reason undoubtedly is that these science-methodology terms have become so ingrained in our culture and society that we cannot imagine a world in which they do not exist (in their modern meaning). Take 'discovery', for instance. It is only in the mid-16th century that this word was introduced in English to denote 'the fact of obtaining knowledge of something which was not known', thanks to the discovery of, until then, unknown parts of our globe. "Before discovery history was assumed to repeat itself and tradition to provide a reliable guide to the future; and the greatest achievements of civilization were believed to lie not in the present or the future but in the past, in ancient Greece and classical Rome" ([1], p. 61). Even facts did not exist (in the modern meaning of 'things that have, through experience, been proven to be true') before the Scientific Revolution. Philosophers were rather preoccupied with 'phenomena', everything which was generally accepted to be the case, and with 'saving' or 'salving' those phenomena.

In the subcategory of science-content terms, we can in the first place make the classic distinction between theoretical terms (i.e., terms whose semantics depends upon a scientific theory) and observational terms (i.e., terms that refer to entities that are, supposedly, directly observable in the sense of unaided perception). More interesting for our purposes is the less classic distinction between quantitative and qualitative progress in science-content terminology. The former kind of progress concerns the steady increment of scientific terms and phrases, coined to denominate new discoveries and insights, either by appropriating vernacular words for a new, scientific use (e.g., 'gravity', a synonym of 'seriousness' for 'downward acceleration of objects') or by inventing new (metaphorical) terms (e.g., 'gravitation', from the Latin verb 'gravitare' for the attracting force behind gravity). This kind of progress or change has not yet been systematically documented, although we do of course have science dictionaries and semantic case studies of crucial scientific terms like 'evolution' [5]. The second, qualitative kind of progress mainly concerns improvements in the correspondence between scientific linguistic tokens and their referent(s). This kind of progress is much more tentative and ambivalent than the quantitative sort but nevertheless real, as we will explain and illustrate in the next section.[3]

2. Linguistic tokens and their referent(s): a systematic survey.

Wittgenstein [6] claimed that it was the task of science to investigate matters of fact, whereas philosophy merely had to clarify the meaning of terms, i.e., spot, diagnose and 'cure' 'sick' scientific terms. Some of his enthusiastic followers took this advice too much to heart or too literally though (as followers are wont to do). Their critics mocked that they rather resembled neurotic carpenters than the linguistic doctors Wittgenstein had in mind as they devoted all of their time to burnishing and sharpening their tools (language) instead of using them to cut and shape wood (develop insights and theories about philosophical questions). One of these critics was Karl Popper [7]. He argued that the view that the precision of science and of scientific language depends upon the precision of its terms was certainly very plausible, but none the less a mere prejudice. Philosophy, he observed, "which for twenty centuries has worried about the meaning of its terms" (p. 17) was appallingly vague and ambiguous, while a science like physics,

[3] These two kinds of change or progress can of course not be seen, independently from each other, in that the qualitative kind often involves, or is accompanied by, the introduction of new terms.

which worries hardly at all about terms and their meaning, but about facts instead, has achieved great precision. Scientists, Popper – a physicist by training - wrote, do not overburden their terms. “We try to attach to them as little weight as possible. We do not take their ‘meaning’ too seriously” (p. 18).

Popper in the first place makes a classic logical mistake by assuming that there necessarily exists some kind of causal or explanatory relationship between two correlated features of modern philosophy: on the one hand its (alleged) vagueness and ambiguity and on the other hand its preoccupation with terms and their meaning. It is furthermore of course correct that the “great precision” of the (mathematical) sciences does not (primarily) depend upon the precision of the linguistic notation system that scientists use. It is rather a result of the rigid precision of their mathematical notation systems. However, this does, like the (alleged) indifference of physicists to the exact meaning of terms, not necessarily say much about the (lack of) importance of linguistic notation systems to science in general and to what might be called the ‘terminological’ (as opposed to mathematical) sciences in particular.[4] We will briefly present a survey of various possible dysfunctions in the relationship between terms and their referent(s) and also give examples of concrete (historical) dysfunctions that have been, or could be, (further) resolved or at least alleviated. Scientific terms can, as we shall see, not only be imprecise, they can also be meaningless, indiscriminate, inapt and ambiguous. Resolving or alleviating these dysfunctions ipso facto improves the communication and collaboration between scientists, and thus allows science to proceed.

2.1. Meaningless terms.

Many terms do not have a concrete referent in the real world, nor are they inspired by concrete phenomena in that world or do they qualify a referent or referents. They are, in this empirical sense, completely ‘empty’. However, that does not necessarily mean that they are meaningless, since most ‘empty’ terms do have a ‘mental’ referent, i.e., they refer to an idea or concept.[5] This is the case with fictional figures and beings like James Bond, mermaids, unicorns, and (for atheists) God; with fictional places like heaven or hell and with terms like nobody and zero. These words may not designate anything in the material world (i.e., they do not have a real-world content), even though people who use them may think so, but they do designate something in the mental world of these persons (i.e., they have a mental-world content) and can, in this sense, even have a huge impact on their thinking and behavior (i.e., be very meaningful, not only because of their epistemic denotation but also because of attached emotional connotations). This

[4] Concepts are as important in the mathematical sciences as they are in the non-mathematical sciences. That is the reason why we speak of ‘terminological sciences’, not of ‘conceptual sciences’.

[5] In some exceptional cases, terms have a referent in the real world (i.e., they are not empty) that differs from the mental referent. The classic example, here, is the planet that we call Venus. The ancient Greeks saw this wandering star or planet rise two times a day, in the evening and in the morning, and consequently assumed that there were two planets: Hesperus (the evening planet), initially considered to be the son of Eos (the Dawn) and the Titan Astraeus (but later said to be the son or brother of Atlas) and his half-brother Phosphorus (the morning planet). Both terms had one and the same real-world referent (Venus) but a differing mental-world referent (Hesperus and Phosphorus). In standard philosophy of language, this classic semantic puzzle (also called Frege’s puzzle) is of course explained in a somewhat different way: Hesperus and Phosphorus have the same referent (i.e., they refer to the same object in the real world), but they differ in ‘sense’ or mode of presentation because they present Venus in different ways (i.e., Venus as seen in the evening and Venus as seen in the morning).

impact can be benign (i.e., a child that is comforted by the 'presence' of its fictional friend) or malignant (i.e., a man who kills his son to soothe a vindictive God).

Likewise, scientific terms can be empirically empty but at the same time refer to important ideas or concepts and, in this mental sense, be extremely meaningful and important. The term 'zero', on which, paradoxically, much of the modern world is based, is a good example [8]. Meaningless scientific terms, by contrast, are empty terms whose scientific relevance or meaning was solely derived from their alleged empirical content. Once this empirical content was falsified, these terms became, scientifically, meaningless. Examples are the supposedly space-filling substance 'ether'; 'phlogiston', the non-existent chemical or element that, until the 18th century, was thought to be released during combustion or oxidation and Johann F. Blumenbach's 'Bildungstrieb' or 'nisus formativus': a vital energy (as opposed to mechanical force) that allegedly was central to the phenomena of generation, growth, nutrition and reproduction. Such terms (i.e., their mental referent) sometimes inspired important scientific research (e.g., the Michel-son-Morley experiment that falsified the existence of luminiferous ether and that was, in the standard account, one of the sources of inspiration of Einstein's theory of special relativity) but in the first place fostered the illusion of knowledge, one of the major obstacles to scientific discovery.[6] The 'unmasking' of such terms as 'empty' can, in this sense, be considered an important exponent of qualitative progress in our linguistic notation systems (as used in, or applied to, science).

2.2. Imprecise terms.

Many terms are not empirically void but, nevertheless, very vague and difficult to define. Put differently: it is difficult to describe their real-world referent or the real-world phenomena by which they are inspired. John Herschel [9] spoke in this respect of "indefinite" terms, "as hard or soft, light or heavy (terms which were at one time the sources of innumerable mistakes and controversies)" (pp. 20-21) and of "excessively complex" terms, "as man, life, instinct" (p. 21). Other examples are 'time' (physics) and 'play' (biology and psychology). In some cases, this vagueness is so pronounced that the scientific meaning of the terms in question can be doubted. The term 'consciousness', for example, is so hopelessly vague that Mayr [10] deemed it unfit for "detailed discussion" (p. 74; he probably meant to say 'scientific discussion' as it is one of the most discussed concepts in philosophy). However, Herschel's examples of 'excessively complex' terms nicely illustrate that modern science can, nevertheless, render imprecise terms more meaningful: we have, compared to Herschel and his contemporaries, a much better, more circumscribed and accurate idea of the referent of terms like 'man', 'life' and 'instinct'.

[6] Harari [11] speaks, in respect with the Scientific Revolution, even of "a revolution of ignorance. The great discovery that launched the Scientific Revolution was the discovery that humans do not know the answers to their most important questions" (p. 279). Interesting, in this respect, is that "During the fifteenth and sixteenth centuries, Europeans began to draw world maps with lots of empty spaces (…)" (p. 319).

2.3. Indiscriminate terms.

Indiscriminate or monolithic terms are terms whose real-world referent(s), at a certain point in time, turn(s) out to be more complex and multifaceted than the use of single and unqualified terms suggests. Put differently: terms often turn out to be in need of refinement and qualification for not capturing the full subtlety and complexity of reality. Julian Elliott [12], an educational psychologist, for example, has argued for the abandonment of the label ‘dyslexia’ because it has become impossible to meaningfully separate dyslexic readers from other poor readers. The term was coined in 1887 by Rudolf Berlin for a severe form of word blindness, despite normal intelligence. Now that it has become clear that there exist many forms and degrees of word blindness, we probably should try to agree on a redefinition of the term, rather than abandon it. The distinction between polythetic and monothetic definitions and that between categorical and dimensional definitions can, in this respect, be helpful. The term ‘gene’ is, to many scientists, a monothetic-categorical term in that all genes (1) share a function and are made of, or rely on, the same ‘stuff’ (sequences of nucleic acids) and (2) are categorical entities (there are no gradations between genes and non-genes). The paradigmatic example of a polythetic-categorical term is Wittgenstein’s ‘game’. It refers to a large number of diverse activities that, according to Wittgenstein, share certain characteristics, none of which is ‘essential’, i.e., necessary or sufficient, for membership of the class of games. The terminology that we use for mental disorders is, likewise, generally described as polythetic-categorical, meaning that disorders are considered present in individuals when a certain combination and number of symptoms are observed and completely absent when these symptoms are not observed. One problem, associated with this terminological categorization, is that it makes abstraction of the fact that many mental disorders are characterized by gradations or dimensions, hence the call for a polythetic-dimensional terminology [13].

2.4. Ambiguous terms.

One of the most common forms of terminological dysfunctionality in science is caused by the several, often related meanings that many words and phrases have (cf. the two meanings of the phrase ‘the Scientific Revolution’). Semantic multifariousness is, in itself, of course not dysfunctional. On the contrary, conceptual pluralism is the norm for epistemic terms. This pluralism only becomes potentially problematic if scientists and scholars do not (fully) realize or do not want to acknowledge that they attach different meanings to technical terms or that these terms are used in different ways. In this case, we must speak, not of multifaceted terms but of dubious or ambiguous terms. Herschel [8] put it thus: “But, what is worst of all, some, nay most [terms], have two or three meanings; sufficiently distinct from each other to make a proposition true in one sense and false in another, or even false altogether; yet not distinct enough to keep us from confounding them (…)” (p. 21). Charles Darwin, for example, confusingly used the term ‘isolation’ for both geographical and reproductive isolation and ‘variety’ for individual and populational variation. Hume [14] points out that situations where “disputants affix different ideas to the terms employed” (p. 53) in a controversy are particularly problematic. This is often the case when a controversy “has been long kept on foot” (ibid.). Mayr [10] makes the same analysis: many controversies in the history of science "were caused almost entirely because the opponents referred to very different concepts by the same term" (p. 44).

2.5. Inapt terms.

Many new terms come into being as metaphors (language has been said to be a dictionary of dead metaphors). This is one of the reasons why metaphors are so important to science as this enterprise is, of course, 'in the business' of discovering new phenomena and developing new insights. Many of these scientific metaphors are inappropriate and, in some cases, even outright misleading: biological 'evolution' (from the Latin 'evolutio', the noun of action from the verb 'evolvere'*)* is not 'an opening of what was rolled up', most so-called 'planets' (from the Greek 'planasthai', 'to wander') do not wander through the universe, nature does not 'select' and genes are not 'selfish'.[7] In this last case, the transition from inapt and misleading metaphor to apt or neutral literal term is still not finished.[8] Literal terms can also be inapt though, or initially be perceived as such. The meta-scientific term 'scientist', an 'illegitimate' hybrid of the Latin term 'scientia' and the Greek suffix 'ist' (from *-ιστής*) is a classic example [4]. Coined by the polymath William Whewell in 1833, as a substitute for 'natural philosopher', it was, because of this 'illegitimacy', very slow to become established, especially in England (versus the United States). So-called Whiggism is a good example of an inapt literal science term (if we consider history to be a science). It refers to an approach of the past that is colored or distorted by a contemporary perspective or agenda. Professional historians should, in principle, interpret the past, not from the present but from the perspective of the past. Part of the reason why the abandonment, by professional historians, since the 19th century, of an amateurish Whiggish perspective in favor of a historical perspective, is not better or more generally known, and maybe (and more importantly) also why historians themselves still wrestle with this transition, may be that it has not been labeled very well. We live in the present and are therefore indeed inclined to interpret the past from that present, in the same way that we, for example, were once naïve geocentrists (as earth dwellers), anthropocentrists (as human beings) and ethnocentrists (as members of a certain society and culture). An apt alternative for the phrase 'Whig history' is therefore 'presentcentrism'. The opposite, modern and more objective interpretation of history should then be referred to as 'historiocentric'. The phrase 'the Scientific Revolution', for example, is clearly presentcentric and therefore potentially misleading, whereas the phrase 'the Reformation in (natural) Philosophy' is historiocentric.

Conclusion

The topic of scientific notation systems is broad and diverse. It ranges from mathematical notation systems to the role of metaphors and rhetoric in science. The literature already covers many of these subjects but there are still some lacunae. One lacuna was recently addressed by Wootton [1] in his study of science-methodology terms that reflect the radically new cognitive attitude of our 17th century ancestors towards both received knowledge and the acquisition of new knowledge. In this short article, we have briefly

---

[7] Ironically, true 'planets', i.e., planetary-mass objects that do not orbit a star but wander freely through space, are, in modern scientific parlance, called rogue, nomad, interstellar or orphan planets.
[8] Dawkins [15] has tentatively admitted that he should have used a different metaphor.

touched upon what we consider to be a second major lacuna: qualitative dysfunctions and improvements in non-metaphorical science-content terms and phrases. We associate scientific progress with better technology and, linguistically, with a steady and incremental increase of scientific terms. It is less well known and acknowledged that it also was and is accompanied by the development of an ever more refined, less ambiguous and more accurate and meaningful terminological apparatus.

REFERENCES

[1] Wootton D., The Invention of Science: A New History of the Scientific Revolution, U.S., 2015.
[2] Mazur J., Enlightening Symbols: A Short History of Mathematical Notation and Its Hidden Powers, U.S., 2014.
[3] Brown T.L., Making Truth: Metaphor in Science, U.S., 2003.
[4] Ross S., 'Scientist: The Story of a Word', Annals of Science, U.S., vol. 18, pp. 65-85, 1962.
[5] Bowler P., The Changing Meaning of Evolution, Journal of the History of Ideas, U.K., vol. 36, pp. 95–114, 1976.
[6] Wittgenstein L., Tractatus Logico-Philosophicus, U.K., 1922.
[7] Popper K., The Open Society and Its Enemies, vol. 2, The High Tide of Prophecy: Hegel, Marx, and the Aftermath, U.K., 1945.
[8] Kaplan R., The Nothing that Is: A Natural History of Zero, U.K., 2000.
[9] Herschel J., Preliminary Discourse on the Study of Natural Philosophy, U.K., 1831.
[10] Mayr E., The Growth of Biological Thought: Diversity, Evolution and Inheritance, U.S., 1982.
[11] Harari Y.N., Sapiens: A Brief History of Mankind, U.K., 2014.
[12] Elliott J.G., Gibbs S., Does Dyslexia Exist? Journal of Philosophy of Education, U.K., vol. 42, pp. 475-491, 2008.
[13] Kecmanovic D., The Gradation of Psychopathology: For Better or for Worse, East Asian Archives of Psychiatry, China, vol. 22, pp. 75-81, 2012.
[14] Hume D., An Enquiry Concerning Human Understanding, U.K., 1777.
[15] Dawkins R., The Selfish Gene: 30th Anniversary Edition, U.K., 2006.